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Cover photo: Adult male great horned owl from the study area. (Author photo; no date)

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Great Horned Owls at the Los Alamos National Environmental Research Park: Population Survey, Nesting Biology, and Management Activities to Protect Peregrine Falcons

by

David A. Ponton

BACKGROUND

In 1979, great horned owls (*Bubo virginianus*; GHOs) began preying on young peregrine falcons (*Falco peregrinus*) that had been introduced into the traditional peregrine eyrie at Los Alamos as part of recovery management of this species. At that time the peregrine falcon was listed as endangered under the 1973 Endangered Species Act (16 U.S.C. 1531 et seq.). No predation had previously occurred as far back as 1964 when observation at this peregrine eyrie began. Control measures were immediately started for GHOs to protect peregrine falcons, and a study was launched to assess the GHO population in the Los Alamos area and to develop management techniques to protect peregrine falcons from owl predation. These data were not previously formalized and published but are being reported here for archiving, to meet a request for other endangered species work, and to support pending peregrine falcon reporting.

STUDY AREA

The study area was the middle-eastern portion of the Pajarito Plateau in the Jemez Mountains, New Mexico, which is an area that is mostly within Department of Energy land that was designated as the Los Alamos National Environmental Research Park in 1976. The study area includes Los Alamos County land on the north boundary of the research park to fully encompass the critical territory of the peregrine falcons preyed upon by GHOs. The Pajarito Plateau was formed by two major pyroclastic volcanic eruptions that deposited tuff (distinctively identified as Bandelier Tuff) up to 300 meters thick on the eastern side of the volcano, forming a plateau (Burton 1982). These eruptions are mainly responsible for the formation of the Jemez Mountains that rise to the west of the plateau. Erosion of the tuff in the 1.1 million years since the last eruption formed numerous canyons in the plateau. Canyons in the central portion of the Pajarito Plateau run west to east and are abundant, approximately equally spaced, and roughly parallel. The mesas between the canyons have tops just over 7000 feet in elevation and mostly interconnect on the western portion of the plateau where it transitions upwards into mountain slopes (USGS 1952a, USGS 1984). The mesa tops were piñon-juniper woodland at the time of the study. (Piñon pine was dramatically reduced in the entire area in 2002–2004 by a bark beetle infestation.) The north-facing sides of the canyons are generally talus slope with some small sections of cliffs or steep exposed areas of tuff, and have a mixed-conifer plant community in the larger canyons. A ponderosa pine park community exists in much of the canyon bottoms, giving way to piñon-juniper woodland in the drier areas. The south-facing sides of the canyons have vertical cliffs with a talus slope at the base, the talus slopes having a piñon-juniper woodland plant community at the time of the study. The erosion of the softer portions of exposed tuff creates numerous holes and caves in much of the cliff faces that distinguishes this substrate and provides thousands of choices of protected nest sites that are used by cliff-nesting raptors and ravens.

A section of the Pajarito Plateau showing the core territory of peregrine falcons nesting in Pueblo Canyon with owl nest locations indicated and approximate owl territories outlined. (LANL photo, 1989)

DESCRIPTION AND CHARACTERISTICS

The GHO occurs continent wide, with 13 subspecies recognized by the Integrated Taxonomic Information System (ITIS 2008). The subspecies *B. v. pallescens* is attributed to the region; however, the birds nesting in the Jemez Mountains have much darker plumage. All birds nesting or trapped on the study territory had dark barring with dark mottling between bars as on the back feathers and the leading-edge upper surface of flight feathers. The breast feathers and trailing edge of flight feathers have a tan color between bars. The legs are tan. The overall impression is that of a dark bird with tan background color on wings, tail, and portions of the breast. Only one example of the *pallescens* subspecies plumage was encountered in the study area, a male that moved into a vacated territory in Pueblo Canyon. He exhibited the light barring and the light gray background color that is described for the subspecies, with white legs. Based on nearly 150 specimens at the University of New Mexico ornithological collection, Robert Dickerman described the situation in New Mexico as follows:

Adult male great horned owl from the study area exhibits dark plumage with a tan background color that is very different from the light-plumaged subspecies recognized for the region. (Author photo; no date)

> There are two nesting populations in New Mexico, a "lowland" (desert/grassland) pale population correctly called *pallescens*, and a darker, more heavily barred "highland" population for which I at the moment call "piñon-juniper." That subspecies exists as island populations on our isolated [mountain] chains here (to at least the Guadalupe Mts.) but in a continuous distribution from northern New Mexico to southern Idaho. It is an undescribed subspecies (Dickerman 1988, pers. comm.).

The mix was recognized by Owling.com as follows (2008):

B. v. subarticus is found from E. British Columbia east to the Hudson Bay and south to at least the Northern U.S. The described race *occidentalis* of the Rocky Mountains has been included here. A mix with *lagophonus* or *pallescens* (or an unnamed race) may inhabit south to Arizona.

Physical Dimensions

Measurements made on some trapped individual owls were consistently smaller than published species averages but the sample was too small to be significant. The values are included in the data table in the Appendix.

Prey

Nests contained some uneaten rodents: valley pocket gopher (*Thomomys bottae*), Mexican woodrat (*Neotoma mexicana*), cottontail rabbit (*Sylvilagus* spp.), and vole (*Microtus* spp.). Remains of other prey were feet of cottontail, numerous unidentified rodent bones, feathers from common flicker *(Colaptes auratus*), scrub jay (*Aphelocoma corerulescens*), bluebird (*Sialia* spp.), nestling raven (*Corvus corax*), and a few unidentified birds. Nests were twice found to contain three uneaten pocket gophers, indicating the abundance of this species, consistent with regular evidence of gopher burrowing in the canyon bottoms and on mesa tops where there is sufficient soil, plus their nocturnal activity increasing their vulnerability as prey of GHOs. Peregrine falcon remains were found associated with owl feathers, activity, or in places where no other predator had access. (See section on predation on peregrine falcons below.) The taxa of prey of the GHO reported in the literature are highly varied, earning the species the description of opportunistic generalist predators. Diet represents the local availability of prey, depending on geographic region and habitat (Houston et al. 1998). One study in the Southwest found *Neotoma* to represent 5% of the prey items, *Sylvilagus* 1%, *Thomomys* 11%, and birds 2%, which computed to 16%, 9%, 26%, and 3% of biomass, respectively, the remainder was varied or unidentified (Ganey and Block 2005). The cursory examination of prey utilized by GHOs in the Pajarito Plateau suggests an even stronger utilization of *Thomomys* than the comparison, but otherwise similar. The utilization of a raptor such as the peregrine falcon as prey is a rare opportunistic event.

Vocalization and Territory

The literature is not helpful in understanding the basics of vocalization. The male frequently calls with a universally familiar four-note vocalization in and out of the breeding season that could be spelled as *who-ho_whooo whooo,* where the underscore denotes a rest. Some males frequently miss the first note, producing a three-note call, still with the distinctive rest. The female calls with an eight-note vocalization, generally in the breeding season, *who-ho-ho-ho_ho-ho-ho whoo* where the middle six notes are very short. Individuals may leave out or fail to enunciate all eight notes, but the pattern of the very short notes ending with a longer note is consistent. When a wild owl flew over the head of a tethered male, the tethered owl made a shriek like a fighting tomcat. Copulation of wild owls was witnessed one time, the male vocalizing repeatedly while leaning forward and facing different directions, the female vocalizing once, then the male landing on the females back and both owls vocalizing simultaneously.

The greatest number of owls vocalizing and the most sustained vocalization sessions occurred on moonlit nights, but some moonlit nights had negligible vocalization.

When fledged young are approached by a human, the adult that seems to always be roosting nearby, probably the female, makes a "put, put" call, not loud.

GHOs are territorial, and, much like song birds, the males mark their territory by vocalizing from perches within that territory (Miller 1930). From December through March, territorial hooting is backed up by aggression (Baumgartner 1939). Also, hooting is mating solicitation. By the time their eggs have hatched, the frequency of hooting has diminished, but it serves to maintain the already established territories. By July or August, adults are found outside their original territory (Baumgartner 1939, Errington 1932), and young owls are becoming independent.

POPULATION SURVEY

Methods: Twilight, nocturnal, and dawn aural surveys were conducted, listening for vocalizations and attempting to stimulate vocalizations with a tape recording of a male owl vocalization. Cliffs in canyons (Barrancas, Bayo, Pueblo, North, Los Alamos, Mortandad, Sandia, Pajarito, Water, Indio, and Ancho) (USGS 1952a, USGS 1952b, USGS 1952c, USGS 1984) were surveyed visually for nesting activity. Other biologists were alerted to the need for sightings or evidence of nesting. Los Alamos National Laboratory (LANL) security guards were enlisted to report owl activities they noted during nighttime patrols. A banding permit was obtained and trapping and banding was conducted for a possible recapture population estimate.

Results: GHOs were found to be common in the area, with some daytime sightings, some nocturnal sightings, and numerous twilight and nocturnal vocalizations heard in numerous locations and habitats ranging from ponderosa pine forest to piñon-juniper mesa tops to mixed habitat types in the canyon complexes of the plateau. Nocturnal vocalizations were often negligible, but occasionally prolific. A one-person aural survey on the night of March 21-22, 1981, a moonlit night, heard a pair north of the Sportsman's Club shooting range in Rendija Canyon, a male east of the range, a male on North Mesa, a male and a pair in Barrancas Canyon, a male in Bayo Canyon, a male in lower Pueblo Canyon, and a male in lower Sandia Canyon.

In the most intensely studied area, Pueblo Canyon and Bayo Canyon, the territories of three pairs were roughly determined in 1980 and beyond. One pair utilized Bayo Canyon from the upper forked area of the canyon to the end of Kwage Mesa. This pair was banded but their nest was never located. Another pair resided in Pueblo Canyon, with a territory from the emergency landing strip to the marsh area that formed below the former water treatment plant, which is in the center of the area where Pueblo and Bayo canyons have no intervening mesa. One night, this pair and the Bayo Canyon pair could be heard in a vocal standoff that seemed to be reinforcing a boundary between their territories that led from the tip of Kwage Mesa to the northeast. A third pair nested in the prominent side canyon off of Pueblo Canyon that divides Kwage Mesa from North Mesa and is informally called North Canyon. This pair's territory extended west onto North Mesa, based on reports by residents of regular sightings and a sighting by the author. A pair was heard in lower Pueblo Canyon on the mesa above the intersection of State Road (SR) 502 and SR 4, but a nest was not located or a territory determined. Thus, a three-mile section of Pueblo Canyon contained three active pairs. With the pair known in Bayo Canyon and a male in the eastern terminus of Bayo Canyon that was probably paired, there were five pairs in a total area of seven square miles, or one pair per 1.75 square miles. Pueblo Canyon experienced considerable management-induced turnover that affected the nesting density and territory boundaries, which will be discussed later.

Male owl trapped on a bal-chatri trap in Los Alamos Canyon and banded. This bird was subsequently trapped in Pueblo Canyon, replacing a male that was removed from that territory, was released there wearing a radio transmitter, was injured four months later by a car near White Rock, and was rehabilitated by Kathleen Ramsay and re-released in Pueblo Canyon. (Author photo, 4/15/81)

A male was captured and banded in the forested bottom of Los Alamos Canyon, but the existence of a pair, territory, or nest was never determined in that canyon. A pair was located in Sandia Canyon with a nest in the side canyon north of the LANL security force firing range. The territory of this pair was not established but sightings reported by personnel at the Meson Physics Facility suggested that the top of the mesa was included in their territory. In Pajarito Canyon, a nest had been known at least as far back as 1955 to be in a pothole in a cliff just above Technical Area (TA) 18, with people from the site watching the young develop each year. The adults were frequently sighted in the canyon by resident workers, roosting in trees or on utility poles, with two sightings on the mesa between Pajarito Canyon and Three-mile Canyon and two sightings down canyon from the nest as far as two kilometers (Lonnie Morgan, pers. comm.). Reports of owls on the mesa above and west of the nest suggested that that area was included in their territory. This pair was banded by the author. A pair was located in Indio Canyon with a nest in a pothole on a low cliff. One adult was banded, but a territory was not determined. An individual bird was found roosting in Water Canyon east of SR 4, and on a different occasion male vocalizations were heard simultaneously east and south of that location, but pairing or a territory were not determined.

In lower Ancho Canyon in the area where SR 4 passes along the bottom of the canyon, a pair was observed and heard repeatedly and copulation was witnessed once, but a nest was not located. One adult was banded. Based on vocalizations and trapping location, the territory included the cliff above the road, the pine forest area across the road from the cliff, and the open area around and to the south of the road intersection with the Ancho Canyon Firing Site road.

One night, a male was heard up the firing site branch of the canyon simultaneously with the male in the main canyon area, suggesting two territories in that canyon complex.

A pair was heard in lower Mortandad Canyon east of SR 4, but a nest was not located or a territory determined. Vocalization was reported in the White Rock Overlook area, but canyons to the north of that point were searched without finding nests or other evidence. Reports of vocalizations in the condominium area on the north rim of Los Alamos Canyon led to searches of the cliffs below that area on 4/20/88, but no nests or evidence were found. In 1988, vocalizations were reported in lower Alamo Canyon and lower Capulin Canyon (T. Johnson, pers. comm.), furthering the pattern of GHOs occupying the lower portions of all canyons in the Pajarito Plateau.

GHOs were not detected or reported in the western portion of the Pajarito Plateau along SR 501. This area is more heavily forested and has far fewer cliff nesting sites, but it was not determined if these characteristics were limiting.

Young owl in a nesting cavity in Indio Canyon. (Author photo, 4/26/88)

Nesting and Productivity

Methods: Coordinates of nests were determined by reference to topographic maps. Owl nests were accessed by rappelling or by ladder from below. Nest heights were determined from topographic maps, by scaling of photos of the cliffs, and by proportion to rope length or ladder height. Presence of two adults was assumed except in one case where a male collected for management purposes was probably the mate of a female with young, thus the number of adults is uncertain. Cave dimensions were measured with a tape measure. Brood size was determined on nest visits, nest observing of the Pajarito Canyon nest by owl fans, or on observation of fledged young near the nest.

Results: Nest locations and physical characteristics are presented in Table 1. All but one nest were in cave-like cavities on the tuff cliffs. These cavities are small caves with interiors that are larger than the opening. The one exception was the nest in North Canyon, which was on a large open ledge in an amphitheater-type recess. The height on the cliff face was more consistent with a minimum from the bottom than from the top.

Table 1. Nest Locations and Characteristics

Canyon Cave ID	Coordinates (USGS 1984, USGS 1952c)	Cliff height m	Nest height m	Type	Depth cm	Interior, cm		Opening, cm	
						width	height	width	height
Pajarito	106°15'55.6" E 35° 50'29.1" N	10	9	cave	97	116	76	86	51
Indio	106°15'1.5" E 35° 48'28.1" N	10	6.3	cave	71	61	38	20	24
Sandia	106° 15'10.6" E 35° 52'0.3" N	12	5	cave					
North	106°16'13.4" E 35°53'16.8" N	39	10	ledge	~100	~300	~100	NA	NA
Pueblo 1*	106°15'00" E 35°53'4.7" N	78	15	cave	74	46	36	23	33
Pueblo 2*	106°15'5.8" E 35°53'6" N	88	50	cave					
Pueblo 3*	106°15'3.6" E 35°52'40" N	35	17	cave					

*Pueblo 1, main cliff near power lines; Pueblo 2, main cliff over pine ledge; Pueblo 3, south side of canyon in cliff area below power lines

The history of adult occupancy and productivity is shown in Table 2. Out of 20 nests where broods were reliably observed, there was one brood size of three, 13 broods of two, five broods of one, and one instance of a clutch of two eggs failing to hatch. There was no development in these eggs. Fledging success was not determined.

Table 2. Nest Site Annual History (adults/nestlings)

Canyon Year	Pajarito	Pueblo*	North	Sandia	Indio
1974	2/2				
1975	2/1				
1976	2/2				
1977	2/2				
1978	2/2				
1979	2/2	1/?			
1980	2/2	2/?	2/2 (all removed)		
1981	?/0	?/? Pueblo 1 likely**	0/0		
1982	2/2	2/2, Pueblo 1	0/0		
1983	2/2	2/1 (adult male removed in the middle of the breeding season, female raised 1 young) Pueblo 2	0/0		

Table 2. (cont.)

Canyon Year	Pajarito	Pueblo*	North	Sandia	Indio
1984	2/1		0/0		
1985	2/2		0/0		
1986	2/1				
1987	2/2				2/?
1988	2/2			2/3	2/2
1989	2/0 no embryo development			0/0	0/0
1990	0/0***				
1991	0/0				
1995		2/? Pueblo 3			

*Individual nest caves are designated by a numeral.
**Pueblo 1 had an abundance of rodent bones accumulated below it in 1982, as if it had been used previously.
***New building built near traditional nest cave may have caused owls to abandon that site.

Capture, Banding, Take, Recovery

Methods: Capture and recapture methods attempted for adult owls utilized bal-chatri (BC) traps (Berger and Mueller 1959) with nooses of 50-lb. monofilament dyed brown on flat-black-painted wire cages, mist nets, pole traps, and hoop nets slapped over nest caves accessed by rappelling or with a pole extension from below. Bait included laboratory gray mice, hamsters, and white rats from Health Research Laboratory extra stock; pet-store rabbits; and bantam chickens and domestic pigeons from flocks maintained by the author. BC traps were deployed 10 at a time, distributing them from 100 to 400 meters apart, then checking them at intervals of 30 minutes to an hour. Nestling owls were captured by hand in the nest, the nests accessed by rappelling. U.S. Fish and Wildlife Service (USFWS) bands were used, the author as sub-permittee, permit number 1598 under John Hubbard of the New Mexico Department of Game and Fish (NMDGF). Take was conducted under depredation control permits issued by USFWS and NMDGF to the author. In the control area, owls were tracked by sight and vocalization, or lured with a GHO tape

Author in a climbing harness banding a nestling owl at Pajarito site. (Lonnie Morgan photo, 5/26/83) recording and a live tethered owl, and were taken with a 12-gauge shotgun, a .22-caliber rifle, or BC trap. Territories vacated by management activities were monitored for replacement owls by aural surveys, by means of a tethered male owl that vocalized spontaneously, or with a tape recording of male owl vocalization. Adults were sexed by behavior (adult roosting in nest or close to young was assumed to be female), vocalization, or by size—if the bird was obviously small it was attributed to be a male, obviously large a female, mid range indeterminate. Nestlings were not sexed. A wildlife rehabilitator was notified of the project in case she received banded birds.

Results: GHOs were never caught with mist nets or pole traps. BC traps baited with hamsters accounted for almost all captures, the hamsters maintaining high activity even on cold nights. Hamsters are a similar size and shape to the gophers common to the area and commonly observed as prey. White rats and pet-store rabbits were hardy, but were only used a few times and resulted in no captures. It was not determined if the oddity of white rats/white rabbits was favorable or not favorable to trapping. Laboratory mice ceased activity and sometimes died of exposure on cold nights, thus there were no captures. Pigeons were inactive at night, but one male owl that was highly suspected as a peregrine predator, escaped hunting patrols, and refused rodents as bait on any kind of trap was finally captured in Pueblo Canyon on a BC trap placed in a tree and baited with pigeons. This particular owl was held in captivity due to the capture location in proximity to the peregrine eyrie and its possible behavior conditioning to hunt prey in cavities on the peregrine cliff. Other captured owls were banded and released at the capture location.

Only one banded owl was re-trapped. The re-trapping was with a pigeon-baited BC trap, where the original trapping was with a hamster-baited BC trap. Negative behavior conditioning could explain non-recaptures with hamster bait. The possibility of negative conditioning completely defeats any population estimate by recapture, even if the sample size had been much larger.

The adult female at the Sandia Canyon nest was reluctant to leave the nest, staying after she was captured and banded. (Author photo, 4/29/88)

The females on the Pajarito Canyon nest site and the Indio Canyon nest site were captured with hoop nets slapped over the nest cave. The technique was highly effective for recapture as well, the Pajarito female banded in the first capture in 1982 was recaptured on the same nest repeatedly, the last recapture in 1989. The adult female at the

Sandia Canyon nest was unusual in that she stayed in the nest when approached and would not leave the nest when a hoop net was placed over it from below. She was captured and banded during a rappel from above.

Movement and Replacement

Methods: Trapping by the methods described above was continued and band numbers plotted on topographic maps relative to banding locations. The area in Pueblo Canyon that had owls removed for predation control was monitored for replacement owls by aural surveys, by tethering a live male owl that would spontaneously vocalize, and by a tape recording of a male owl voice in conjunction with a tethered owl.

Results: A banded adult male was recovered two times, once by a pigeon-baited trap, moving one kilometer in 14 months when the male from an adjacent territory was removed, then injured by car impact, having moved five kilometers in four months. (This owl was rehabilitated and released.) A banded nestling was recovered dead seven months after fledging at Española, New Mexico, 23 kilometers to the northeast. A nestling was injured by a car impact two kilometers down the nesting canyon two months after fledging. (This owl was rehabilitated and released.) Another banded nestling was found dead near the nest soon after fledging.

On 5/14/83, the male owl using the canyon along the peregrine cliff in Pueblo Canyon was captured and removed as part of management activities. This owl was held in captivity and recruited for management assistance. On 6/25/83, he was tethered on a pinnacle in the canyon and spontaneously vocalized for two hours. No wild owls responded, suggesting that the territory had not yet been occupied by a new male. On 8/6/83, two male owls were vocalizing simultaneously east and west of the peregrine eyrie. On 8/7/83, a banded male was trapped in Pueblo Canyon, presumably one of the vocalizing males, having moved one canyon north of the banding location in Los Alamos Canyon, and was held in captivity temporarily. On 8/10/83, a young owl was trapped, associated with the adult female that was still at large. On 9/21/83, the banded male that had moved into the territory was released wearing a radio transmitter, the intention being that he hold the territory and always be locatable. However, the antenna broke off the transmitter soon after release so he was not located until being injured by a car four months later, no longer in the territory.

In anticipation of the arrival of peregrines in 1984, a tethered male owl with a tape recording of a male owl was used to attract any owls that might have taken up residence in the canyon. (Experiments conducted outside the study area found that wild owls responded to but did not closely approach tape recorded owl vocalizations, but the addition of a tethered live owl created close approach and loud vocalization from males.) On 2/13/84, a male was attracted and taken; on 3/11/84, the same setup produced no response.

Discussion: The population density of one pair per 1.75 square miles is a higher density than some other studies—one pair per 4.4 square miles in New York (Hagar 1957), one pair per 3.9 square miles in Alberta at the peak of a cycle (McInvaille and Keith 1974), one pair per 3.0 square miles in Wyoming (Craighead and Craighead 1956 p215)—but lower than the one to three pairs per square mile in Kansas (Baumgartner 1939).

Banded owls remained on the Pajarito Plateau except for one young moving to lower-elevation riparian habitat. Absolute fidelity was demonstrated by one female to one nest site for eight years.

A single instance of removing a male from his established territory found no evidence of replacement before six weeks, but two males were vocalizing in the territory in 11 weeks. A single attempt to establish a radio-tagged male owl in a vacated territory failed as the owl left the territory.

Control by hunting and trapping had limited success and did not relieve the predation on peregrine falcons. GHO control was done elsewhere at release sites for young peregrines, with one report in the upper Mississippi Valley of 15 owls taken within a 1.6-kilometer radius of the release site in 1984 (Cade et al. 1988 p560). This seems to reflect a higher density of owls than the Pajarito Plateau, as well as more intensive hunting, and eliminated predation on peregrine falcons at that release site.

OVERLAPPING NICHE WITH THE RED-TAILED HAWK

Red-tailed hawks (*Buteo jamaicensis*; RTHs) were not deliberately studied, but their use of cliffs for nesting caused them to be discovered and recorded during searches for owls. With the focus on owl predation of nestling raptors, the RTH nests could not be ignored.

GHOs and RTHs hunt canyons and mesas of the Pajarito Plateau and both use abundant cavities in the cliffs for nest sites. Where pairs of GHOs are described herein, RTHs were known to nest in Bayo, Pueblo (North), Los Alamos, Mortandad, Sandia, and Ancho canyons, largely overlapping GHO territories and using ledges or large cavities in the cliffs for nests. The overall ratio of known GHO pairs to known RTH pairs was 1.5:1, with a local ratio in Pueblo Canyon in 1980 of 3:1 and Ancho Canyon 2:1.

In two cases, simultaneously occupied nests of the two species were noticed in close proximity. One association was in North Canyon in 1980 where the RTH nest was almost directly above the owl nest, the separation estimated at 20 meters. The RTH nest had an unhatched egg and one young, attaining three weeks of age with no interaction observed between the raptors up until the time the owls were removed to protect peregrine falcons nesting nearby. A second close nesting was in Sandia Canyon in 1988, the RTH nest there active since the mid-60s. The owls were using a cave estimated to be 40 meters to the southeast. No interaction was observed between the species, and the RTH nest, having an unusually large brood of four, suffered no loss of young prior to fledging.

Remains of cottontails in the nests of both species indicate some overlap in their prey.

Discussion: The overall owl to hawk ratio of 1.5:1 is higher than values of 1:1.3 for Ohio and Canada (Springer and Kirkley 1978, McInvaille and Keith 1974), much higher than the 1:3 reported for south-central Montana (Seidensticker and Reynolds 1971) and 1:3 for Jackson Hole, Wyoming (Craighead and Craighead 1956). It is only approached by a cyclic phenomena near Rochester, Alberta, that went from 1:7 to 1:1.2 over five years, where the owl increase was attributed to a cyclic increase of snowshoe hares (*Lepus americanus*) that did not increase the hawk population (McInvaille and Keith 1974). Where others postulate that nest sites are a limiting resource for GHOs because in forest areas they depend on structures built by other species (Craighead and Craighead 1956, Orains and Kuhlman 1956), on the Pajarito Plateau the abundance of cavities in cliffs places no such limit on GHO density.

In forested areas, close nesting has been suggested to be influenced by a combination of the RTHs' tendency to reoccupy the same territory each season, measured in that study to be 83%, and the GHOs' preference in using RTH nests for their nesting sites, measured as 59% (Springer and Kirkley 1978). Several researchers have reported the close nesting of GHO and several hawk species, often noting nest failure of either the hawk, the owl, or both raptors (Houston 1975, Freemeyer and Freemeyer 1970, Luttich et al. 1971, Orains and Kuhlman 1956, Smith 1970, Wiley 1975). One study found correlation between RTH nesting success and distance from GHO activity centers out to one kilometer, then a higher incidence beyond one kilometer, and suggested owl territories and territory boundaries might be contributing factors (Springer and Kirkley 1978).

The non-interaction in the two cases in the Pajarito Plateau is remarkable by comparison and in light of the GHO predation on peregrine falcons. Non-competition for nest sites might reduce interaction. An abnormal event may have triggered the peregrine predation and led to owl behavior conditioning and is discussed in the next section.

PREDATION ON PEREGRINE FALCONS

Background: Predation by GHOs on peregrine falcons is not documented historically to be significant or population limiting. References to GHO predation prior to the peregrine's population crash in the 50s and 60s are scarce. There is one report of an eaten peregrine found near a roosting owl (Hickey 1969, p492), and none in the anecdotal tome of Bent (1938), although other raptors are listed as prey. From the data in Herbert and Herbert (1965), GHOs nested on the same cliffs along the Hudson River for the first two decades of the study of peregrines of the area, with one case of abandonment attributed to GHOs, which would be one in approximately 160 eyrie-seasons (0.6%). There are many reported instances of peregrines nesting in the western U.S. in the first half of the 20th century but with no systematic observations that would reveal predation. Porter and White (1973) discuss 40 eyries know in Utah up to 1970 and describe only one incident of young peregrines killed in the eyrie with an avian predator considered more likely than a ground predator. There are insufficient data to ascribe a frequency.

During the peregrine falcon's recovery from the DDT-induced population crash, peregrine eyries and hacking sites (release sites where captive bred peregrines are provided shelter and food as they progressively become independent) were closely monitored. In the early years of the peregrine falcon recovery program conducted by the Peregrine Fund, hacking sites at historically used cliffs in the eastern U.S. experienced frequent GHO predation on young peregrines, so the Peregrine Fund concentrated its hacking program in wetland areas, a habitat that GHOs do not frequent, benefiting also from the abundance of suitable prey (Cade and Dague 1977). In the upper Mississippi Valley, GHOs took hacked young, prompting owl control. They also took naturally produced young from nesting attempts by returning hacked falcons, and apparently took a nesting adult peregrine (Cade et al. 1988). Continued GHO predation there prevented at least eight pairs from establishing successful nests on cliffs (Burnham 1982, Cade et al. 1989, Tordoff and Redig 1997). In the western U.S., golden eagle (*Aquila crysateous*) and GHO depredations were often the main cause of death of hacked young in reintroduction programs run by the Peregrine Fund (Barclay and Cade 1983, Cade et al. 1988). Considering all nesting peregrines and hack sites in Colorado, natural and supplemented over the period 1973 to 2001, GHOs took almost half of the known predation losses, including an adult (Craig and Enderson 2004). Repeated attacks were reported on one peregrine eyrie in Colorado, with five young killed over a three-year period, resulting in the peregrine falcons relocating (Enderson 2005).

Methods: Peregrine falcons nesting at the Los Alamos eyrie were monitored by LANL to ensure meeting the requirements of the Endangered Species Act. The disappearance of nestling peregrine falcons was investigated objectively each year it occurred by visual searching for evidence of institutional disturbance (LANL or County activity) or, in cooperation with the Law Enforcement Division of the NMDGF, illegal activity by individuals (shooting, illegal take for falconry), natural predation, or other causes.

Feathers and a foot from a young peregrine falcon killed and eaten by a great horned owl below the peregrine eyrie in 1979. (Author photo, 6/6/79)

Findings: 1979: Four young were introduced by the Peregrine Fund recovery program with funding from the NMDGF. Three disappeared from the eyrie. Feathers and a banded foot/lower leg of a young peregrine falcon were found underneath a dead tree directly below the eyrie. The individual feathers were each pinched near the base, which is distinctive for a raptorial bird plucking prior to feeding. Body feathers of a GHO were in the same location. The fourth young was removed by the author and returned to the Peregrine Fund. One GHO hunting on the talus slope below the peregrine cliff was taken under a depredation control permit.

1980: Owls were removed from a nest west of the eyrie in North Canyon prior to peregrine egg hatching. Of three naturally produced falcon young, two disappeared and the third fledged but had several primary feathers lost from each wing. A widespread search found most of the

One feather from a young peregrine falcon showing the pinch at the base that is characteristic of a raptor plucking its prey. (Author photo, 6/6/79)

primary and secondary feathers from one wing of a young falcon along the dry streambed, seeming to have been pulled out in a clump when the wing was pinned in a pounce by a terrestrial predator. Naturally fledged young peregrines have been repeatedly observed to end up on the talus slope near the base of the cliff, so the fact that one young was on the ground all the way in the bottom of the canyon suggests an abnormal, possibly nocturnal, fledging. Thus it appeared that an aerial predator entered the eyrie, took one young and forced the other two into premature fledging. The broken wing feathers observed on the surviving young could have been damaged during the owl attack or by crash landing in brush. The other young falcon ended up in the bottom of the canyon near the streambed where it was more vulnerable to a ground predator. Direct evidence was not found, but a GHO was implicated as the only aerial predator in the area that could strike the eyrie. Apparently, the removal of owls west of the eyrie enabled owls to the east to expand their territory westward, encompassing the peregrine cliff. There was a hint of the concept described in other predator/prey relations of prey finding protection by seeking the "no man's land" between predator territories (Rogers et al. 1980).

1981: Owl territory manipulation was tried with robotic hooters. See the section Other Methods of Depredation Control below. There was no predation and two young peregrines fledged normally.

1982: Owl traps were run early in the season, resident owls were hunted and searches for owl nests were made, but no owls were taken and no nests found. The owls were trap shy and hunter shy, and an active nest in a small cave was not detected until the young owls fledged. The peregrine falcons selected an eyrie cave at the extreme western end of the cliff, the opposite end of the cliff from the owl nest, again hinting at predator avoidance. One of three naturally produced peregrine young disappeared from the eyrie. A GHO feather was found in a grass clump above the eyrie, and the eyrie contained feathers from a nestling peregrine showing that the strike and possible plucking occurred in the eyrie. A raven nest on the cliff close to the owl nest had lost all young when about four weeks old. Plucked feathers from young ravens were found at the top of the talus where young owls had spent time after fledging.

1983: The enduring male owl was finally trapped and removed and an owl-hunting biologist from the NMDGF believed that he had put shotgun pellets in the female owl but she remained healthy. This owl continued to avoid baited traps and slipped away from an attempt to slap a net over a roosting cave. The adult female peregrine and all the small young disappeared from the eyrie. Feathers from the adult female peregrine were found on the talus below. Eggshells from a GHO nest were found on the talus, indicating a successful nest, and additional feathers from the adult peregrine were found to the east of this point, suggesting the carcass was carried in that direction by an owl. One young owl was captured at the base of the talus below the peregrine eyrie, indicating the female owl had completed the reproductive cycle without the male. New male owls occupied the territory in subsequent months, as discussed above.

1984: The male peregrine associated with a young female but did not breed.

1985: The adult male peregrine was last seen in the late afternoon of April 15, actively courting an adult female, but was never seen again. The female remained, and her presence suggested that the male didn't just drift away. A catastrophic event was suspected, but no evidence was ever found. There was not an established pair at this site for the next nine years. In 1993, a mixed pair was discovered at another site on the Pajarito Plateau, and monitoring of both sites found them never to be occupied simultaneously, thus the second site is considered an alternate site.

1995: A peregrine pair reoccupied the site and produced three young. An owl nest was found on the south side of the canyon, an unusual location. A consensus decision was made to not disturb the owls as they were relatively far from the peregrine cliff and disturbance might cause them to move back to the peregrine cliff. Some food buffering was tried. All three peregrine young disappeared from the eyrie. Five plucked feathers from one were found on the talus slope east of the eyrie, the longest feathers showing the pinch mark from being bitten by the beak of a bird of prey. One molted GHO feather was found east of the eyrie but not with the peregrine remains. GHO predation is considered highly likely. Ravens were very active on the east end of the cliff but no young were produced, raising the possibility of GHO predation on nestling ravens. It is possible that the female owl that seemed to have learned to hunt the cavities in the cliff was still occupying the canyon. No peregrines occupied the site for the next 11 years, but the alternate site was occupied and mostly productive through 2006.

2007: A peregrine pair reoccupied the eyrie and produced four young, all fledging normally. If the cliff-hunting owl was at least two years of age in 1979, she would have exceeded the known age record for a wild GHO by 2007 and was likely dead of natural causes.

Discussion: Ground predators generally do not have access to peregrine nesting caves on the face of large cliffs. Raccoons (*Procyon lotor*) are common in the area and might be able to climb portions of the cliff but seem to prefer the canyon bottom. Ringtails (*Bassariscus astutus*) are known cliff climbers (Johnson, pers. comm.) and occur in the Jemez Mountains but have not been seen in Pueblo Canyon. Gray fox (*Vulpes cinereoargenteus*) occur in the canyon but are only modest climbers. Kit fox (*V. velox*) had not been recorded in Los Alamos County during the time of the study, but residents of North Mesa, just west of the peregrine cliff, began seeing them regularly after 2000. In 2008, Mike Steinzig observed a kit fox 40 feet up the cliff in an off-vertical section, entering caves (pers. comm.). Although not pertinent to the study, some peregrine eyries might be accessible to such a predator. Golden eagles are well documented for attacking peregrine eyries (Craig and Enderson 2004) but do not nest in the area of the Los Alamos eyrie and have not been seen at the site during the nesting season in five decades of observations at the site. RTHs nest in the area, but are diurnal and are easily driven away by adult peregrines. When RTHs nested in a side canyon just west of the peregrine's main cliff, they approached and departed their nest from the west to avoid attack by resident peregrines, showing no inclination to approach the main cliff face that the falcons defended. In some years when peregrines were absent, RTHs nested on the main cliff. In 1986, a late-arriving male peregrine aggressively harassed the RTHs as they went to and from their nest as part of his territory establishment behavior even though he was not defending an actual nest. Thus, RTHs would have no opportunity to attack the peregrine's nest cave. Mexican spotted owls (*Strix occidentalis lucida*) are known to nest in a few canyons in the Pajarito Plateau, preferring the more forested portions to the west, and were not encountered in this study in any of the lower portions of the canyons of the Pajarito Plateau. Nocturnal surveys with tape-recorded Mexican spotted owl vocalizations played every 1/4 to 1/2 mile for the length of Pueblo Canyon produced no responses in annual surveys from 2000 to 2007 (David Keller, pers. comm.). Identical surveys from 1995 through 2008 in Los Alamos Canyon, the next canyon to the south, also produced no response (Keller, pers. comm.). Thus, GHOs are the most common, large, aerial, aggressive, opportunistic, nocturnal predators capable of and known to take peregrine falcons at this site, both nestlings and adults.

Terry Johnson compiled data for New Mexico peregrine eyries that include brood disappearance for any cause. In 682 eyrie-seasons, 27 eyries that had been known to hatch eggs lost entire broods (4%). (This rate of total brood loss may be biased low since some broods could have disappeared before they were observed.) Johnson suspected GHO predation in many cases. For example, remains of a young peregrine were found atop a large boulder (typical raptor eating perch) among trees on the talus below one eyrie, and GHOs were heard in the area. Johnson reports that GHOs have often been heard near peregrine eyries, particularly in riparian areas, and have even been observed in cliff cavities on peregrine cliffs (pers. comm.).

Also, at a cliff that was shared by peregrine falcons and Mexican spotted owls, the remains of a young peregrine were found at the base of the cliff, with Mexican spotted owl predation highly suspected (T. Johnson, pers. comm.).

Another New Mexico eyrie that was augmented with four young in 1979 experienced total loss of young by an avian predator, thus two out of three augmented eyries in New Mexico were struck by aerial predators that year (Burnham 1979). Johnson suggested a hypothesis as to why fostered eyries might be more prone to owl predation. His observations of peregrine behavior at many eyries indicate a stillness that pervades the eyrie following the adult female's entry at dusk (pers. comm.). Mutual instincts could explain this collective behavior of adult and chicks that have been together since hatching. Comparatively, captive bred peregrines are introduced into eyries at three to four weeks of age, having been fed in captivity even at night. A "mutual adjustment period" is required between adults that suddenly find large young in place of their eggs and the captive-reared young (Bill Burnham, pers. comm.). Young of this age are too large for the adult female to cover by brooding. The young might rise in the night and use the food-begging wail expecting to be fed. Such nocturnal activity or vocalization could attract owls.

After 1979, the NMDGF discontinued its contract with the Peregrine Fund for augmentation. Natural production was good but losses continued at the Los Alamos eyrie as detailed above, being two partial broods and two complete broods out of the next five nesting attempts at this site, a very high rate of predation for naturally breeding peregrines that does not show randomness. This could be explained by one or more resident owls having been conditioned to hunting cavities on the cliff face by the 1979 experience of successful predation on the fostered peregrines. Owls preying on cavity-nesting ravens, as described above, is further evidence of cavity hunting. In order to assess whether fostering as an initiating event and owl behavior conditioning as a continuing event were significant in a broader sense, state-wide New Mexico data were divided into two groups. For 640 seasons at eyries that had never received augmentation of young, 23 broods were lost (4%). For 42 eyrie-seasons at sites that had ever been augmented with captive-produced young, four broods were lost (10.5%). (Partial losses are not considered because they were not compiled in the total population assessment.) Complete loss of young at manipulated eyries is higher for sites that had ever been augmented, with behavior conditioning of a predator being the only explanation advanced, but a chi-square test indicates a probability greater than 0.05, indicating non-significance. This result is due to the small sample of ever-augmented sites. The comprehensive report on peregrine falcons in Colorado cited earlier in which GHOs account for almost half of the known predation losses of all nesting peregrines and hack sites, natural and augmented, over the period 1973 to 2001, does not separate natural nesting from augmented nesting so any bias for GHO predation on eyries that were ever augmented cannot be detected (Craig and Enderson 2004).

Owl control by hunting and trapping from 1979 to 1983 removed one pair and four individual owls. Owl territory boundaries were evidently disturbed by the pair removal, and the most aggressive pair of owls expanded their territory to the length of the canyon in the front of the cliff. The male of this pair was finally removed in 1983, but the female evaded all control efforts and is believed to be the cliff-hunting owl. The span of time between the first strike in 1979 and the last in 1995 is 15 years, well within the longest age record for a banded and recovered wild GHO of 27 years (Clapp et al. 1982).

OTHER METHODS OF DEPREDATION CONTROL

The difficulties of controlling predation of GHOs on peregrine falcons led to consideration of smarter techniques of protection. Removing established owls in the control program resulted in replacement by owls with no core territory, so predation risk remained but replacement owls did not have a core territory so subsequent control by traditional methods of trapping and hunting became more difficult. Several methods of reducing risk to peregrine falcons by GHOs were tried, all relying on maintaining adult owls in a defended territory while reducing risk of predation on the protected species.

Manipulating Owl Territory with Robotic Hooters

Background and methods: As vocalization is an important part of territory establishment and maintenance, artificial vocalization might be able to influence territory boundaries. Because control efforts had created an open territory in Pueblo Canyon in 1980, multiple robotic tape recordings of a male GHO were deployed in 1981 to suggest that the territory was occupied. Recordings of male GHO vocalizations were transferred to eight-track tape, the standard four-note hoot at intervals of 30 seconds. Electronic controllers were built to turn on the players in hours of darkness every 30 minutes for five minutes. Two players were deployed in open-birdhouse-like sheds in trees at the base of the talus and were independent and thereby asynchronous. Wild owls were monitored by nocturnal aural surveys.

Results and discussion: A male owl occupied the main canyon and did not approach the players. He did pass between the main cliff and the players on one occasion. One of the players was moved to a cave in the base of the cliff below the peregrine eyrie. There was no predation on peregrine falcons that year where there had been the two years before and the two years after, but if there was any connection to the deployment of the players it was probably because they were suspicious, something like a scarecrow, rather than actually acting as a surrogate defending owl. Subsequent experiments with tape recordings and a live owl demonstrated on two occasions very strong response from a wild owl, one of these including a dive over the tethered owl. These observations suggest that a wild owl investigating tape recorded vocalizations and finding no owl to back them up will not be intimidated and not respect the tape recording as a territorial marker.

Buffering the Food Supply

Prey (live or dead) could be introduced to further reduce the hunting pressure. Trials were done in 1995 with road-killed cottontails, placed near the owl's core territory in a conspicuous location fairly inaccessible to ground predators. The carcasses disappeared, with there being some chance that they were utilized by the owls. However, there was weak support for buffering by game managers and no approved plan for release of live buffering prey. Peregrine predation occurred nine days after the last buffering attempt. The attacks were probably due to the size and activity level of the young peregrines in the territory of an owl that was conditioned to hunt in the caves rather than a limited food supply.

Other Techniques for Consideration

Reducing brood size: Young could be removed from owl nests to reduce the brood to one. This will hold the adults on territory while minimizing the food requirements.

Tethering young owls: Owls fledge a month or more before peregrine falcons, and were found to be very hard to keep track of once the young were flying. Young raptors have been tethered for food studies. In this case, it would tie the adults to a specific area and would not open up the territory for other owls to move in. Food buffering could be easily done.

Behavior conditioning against bird killing/cliff hunting: Where six owls were trapped and banded for the population study using BC traps baited with hamsters, none were re-trapped with the same traps and bait. This suggests the trauma of being trapped and handled conditioned them to avoid that trap and/or bait. Young chickens or other such birds could be used as bait in cavities in the cliff that were rigged with a bow-net closure for the front of the cave. Owls attacking the chicks would suffer capture stress and might avoid anything similar in the future. They would still defend their territory, ensuring that new unconditioned owls didn't enter the area.

CONCLUSIONS

At the time of the study, GHOs were a common raptor in the eastern portion of the Pajarito Plateau. The birds are a distinct plumage variant from *B. v. pallescens*, possibly smaller than average *B. virginianus*, but not a named subspecies. Population density at the time of the study was high compared to three other regions, with nest sites not a limiting factor as it is in forested areas, but not the highest recorded. Negligible movement of banded individuals was detected, only one young owl leaving the plateau. One female demonstrated absolute fidelity to one nest site for eight years. Replacement of males removed from their territories took between six and 11 weeks. There is a niche overlap with the RTH, also common, with a ratio of owls to hawks of 1.5:1, higher than any other reported, with the abundant nest sites possibly a factor. There were two instances of very close nesting of GHOs and RTHs with no interaction.

Including peregrine falcons in their diet is consistent with the characterization of GHOs as opportunistic generalist predators. There is evidence that augmentation of young peregrines to the eyrie could have created an unnatural stimulus event that attracted predation and led to behavior conditioning of an individual owl to cliff hunting. Failure rates for peregrine pairs that had ever been augmented were higher than the state-wide rate, although there are insufficient data on manipulated eyries to support significance of the higher rate. Once started, the cliff hunting behavior continued, possibly for the individual owl's lifetime. That other GHOs did not prey on very close RTH nestlings is surprising in light of the peregrine predation, but supports the unnatural stimulus hypothesis for an individual owl. Basic control efforts of trapping and shooting to protect peregrine falcons resulted in replacement by male owls moving from adjacent areas, and possible trap avoidance and shyness to hunters of the key peregrine-killing owl. These experiences indicate that retaining resident owls in their territory using a known nest gives opportunity for close monitoring and better control. This could be negative behavior conditioning rather than the positive conditioning that was actually realized, reducing brood size, and/or food buffering.

Owls will not change their territory due to the presence of robotic hooters that are not backed up by a real owl.

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APPENDIX

Great Horned Owl banding and recovery in the Pajarito Plateau area.
F_B = female determined by behavior, F_S = Female determined by size, M_B = male determined by behavior, M_S = Male determined by size.

Date	Band No.	Age	Sex	Location	Trap	Recovery/Notes
3/20/81	599-29403	AHY	F_B	Pajarito Canyon east side of TA-18 fence	BC	
4/10/81	599-29404	AHY		Bayo Canyon	BC	
4/10/81	599-29405	AHY		Bayo Canyon	BC	
4/15/81	599-29406	AHY	M_S	Los Alamos Canyon	BC	Wing chord 343mm, on first capture. 8/7/83 trapped in Pueblo Canyon, weight 990g. 9/21/83 released with radio transmitter in Pueblo Canyon. 1/28/84 hit by car Pajarito Canyon near White Rock, weight 850g, rehabilitated by K. Ramsay, weight increased during rehab to 1020 g. 4/10/84 released at LA Canyon.
5/15/81	599-29407	AHY	F_S	SR 4 at Ancho Canyon	BC	Wing chord 400mm
5/15/81	599-29408			SR 4 at Water Canyon	BC	Wing chord 381mm
4/30/82	599-29409	AHY	F_B	Pajarito Canyon nest at TA-18	net over cave	Repeated recovery in same nest cave. Wing chord 381 mm; overall length 489mm on first capture. 6/6/86 wing chord 356 mm; tail length, between retrices 216mm, from oil gland 254mm. 6/1/87 tail length, between retrices 212mm, from oil gland 265mm. 5/23/88 weight 1200 g. 5/19/89 same location as banded, incubating inviable eggs.
4/30/82	599-29410	L		Pajarito Canyon nest at TA-18	hand	7/15/85, hit by car in lower Pajarito Canyon, rehabilitated by K. Ramsay, released 9/15/85 same location.

Date	Band No.	Age	Sex	Location	Trap	Recovery/Notes
4/30/82	599-29411	L		Pajarito Canyon nest at TA-18	hand	
5/26/83	599-29412	L		Pajarito Canyon nest at TA-18	hand	
5/26/83	599-29414	L		Pajarito Canyon nest at TA-18	hand	
5/21/84	599-29415	L		Pajarito Canyon nest at TA-18	hand	
8/5/84	599-29416			Captured 5/14/83 Pueblo Canyon, Released at Lake Fork Canyon s. of Fenton Hill		This bird was the aggressive male suspected of peregrine predation, trapped and held in captivity, banded and released in distant location on listed date.
4/27/85	599-29417	L		Pajarito Canyon nest at TA-18	hand	6/85, found dead of skull impact, Pajarito Canyon inside TA-18 fence near road.
4/27/85	599-29418	L		Pajarito Canyon nest at TA-18	hand	
6/6/86	599-29419	L		Pajarito Canyon nest at TA-18	hand	
5/1/87	599-29420	AHY	F_B	Indio Canyon nest	net over cave	Wing chord 365mm; tail length, between retrices 225mm, from oil gland 240mm.
6/1/87	599-29421	L		Pajarito Canyon nest at TA-18	hand	
6/1/87	599-29422	L		Pajarito Canyon nest at TA-18	hand	
4/26/88	599-29424	L		Indio Canyon nest	hand	
4/26/88	599-29425	L		Indio Canyon nest	hand	
4/29/88	599-29426	AHY	F_B	Sandia Canyon Nest	net over cave	Weight 1200 g.
4/29/88	599-29427	L		Sandia Canyon Nest	hand	
4/29/88	599-29428	L		Sandia Canyon Nest	hand	12/18/88, road kill, near bridge over Rio Grande on s. side of Espanola.
4/29/88	599-29429	L		Sandia Canyon Nest	hand	
5/23/88	599-29430	L		Pajarito Canyon nest at TA-18	hand	
5/23/88	599-29431	L		Pajarito Canyon nest at TA-18	hand	